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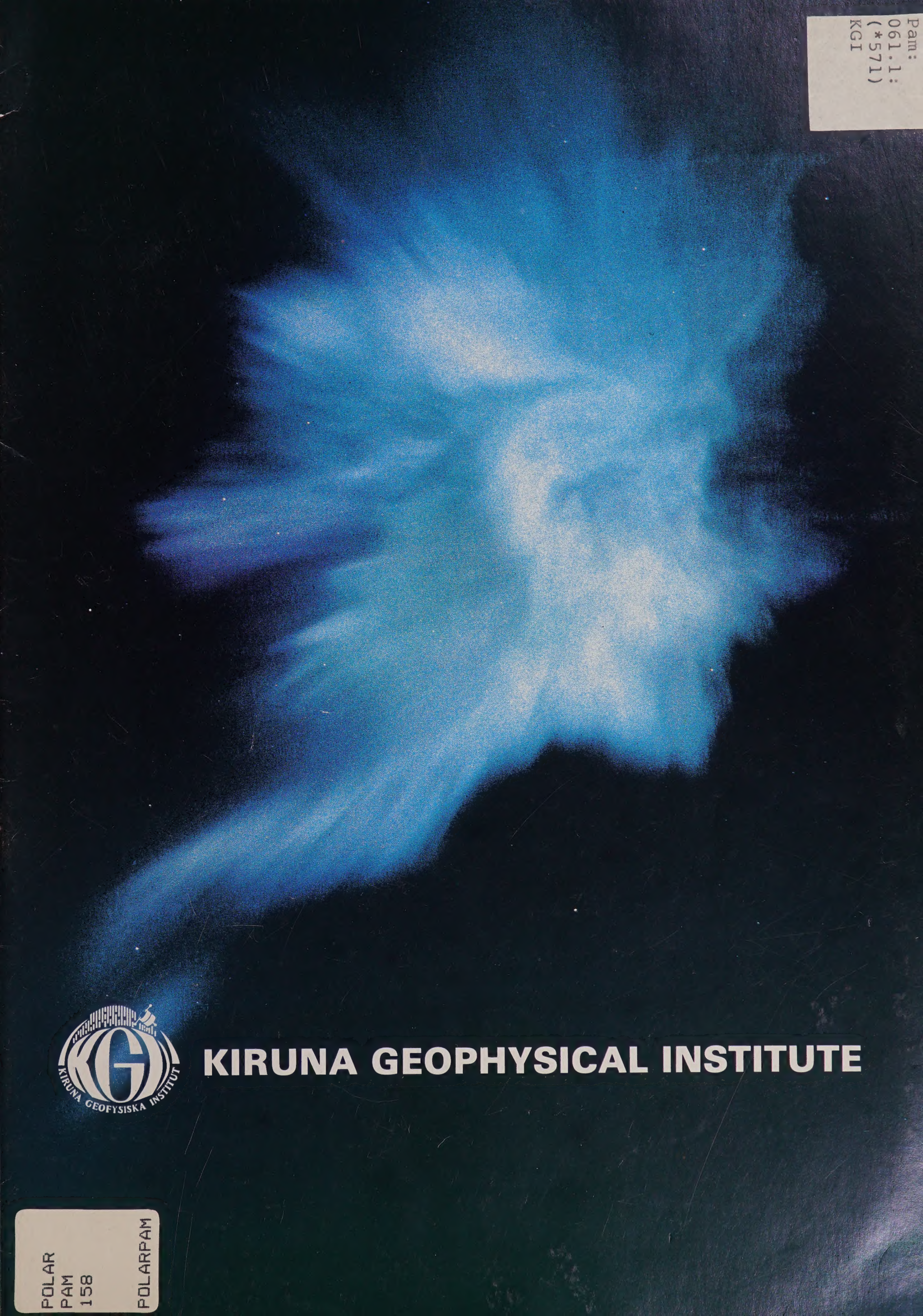

KIRUNA GEOPHYSICAL INSTITUTE

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The auroral oval is a belt with a width of about 5° in latitude. It extends over Iceland, northern Scandinavia, Siberia, Alaska, and northern Canada. Kiruna is situated under the auroral oval and this is the reason for the location of the Institute.

Kiruna Geophysical Institute — the main building in Kiruna.

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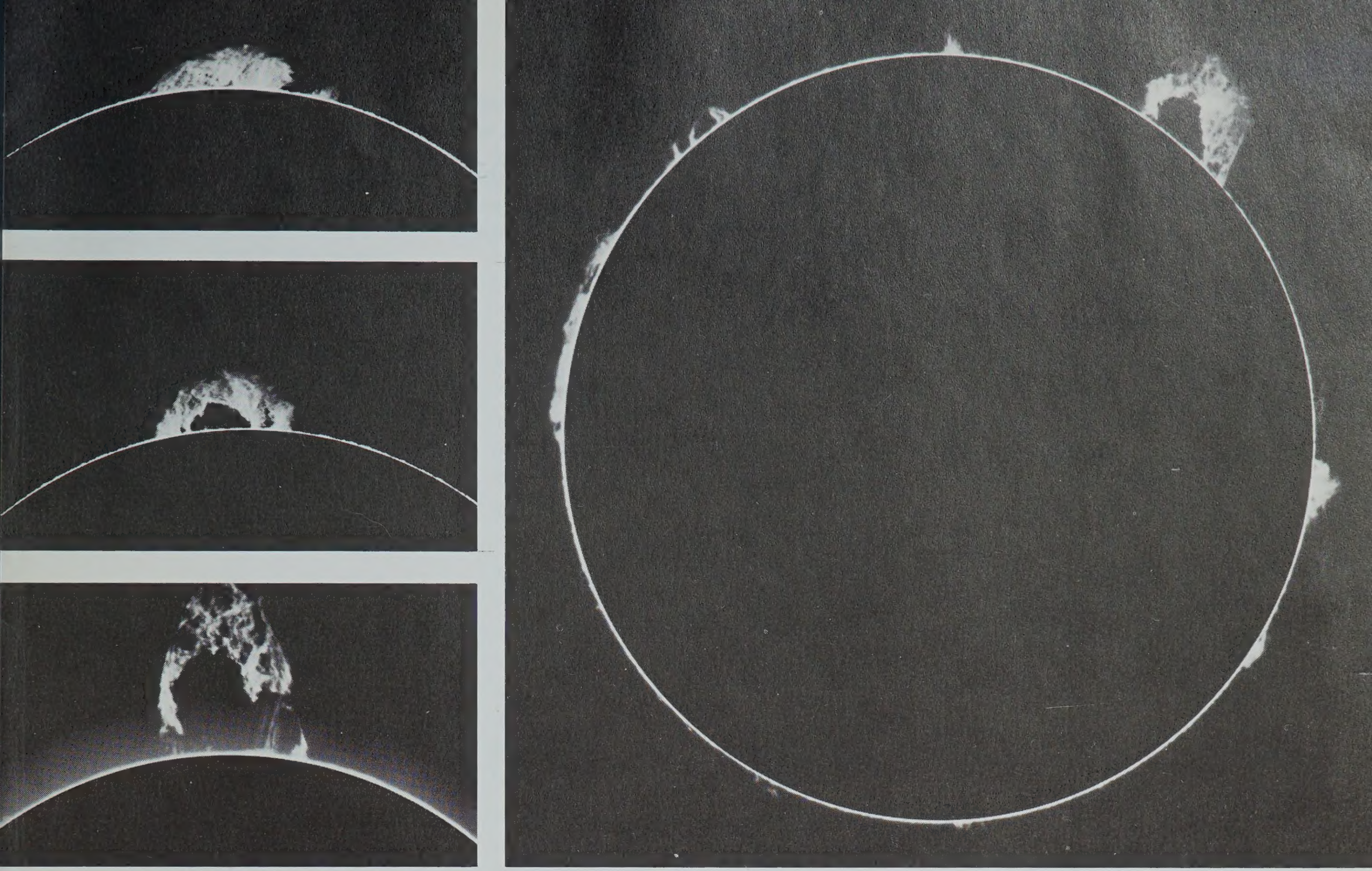

The sun is the basis for life on earth. This sequence of photographs of the solar corona shows the development in time of a prominence associated with a solar flare. Such flare activity gives rise to enhanced electromagnetic wave emissions which reach the earth after 8 minutes. Plasma is also ejected but it takes about 24 hours for it to reach the earth (Photo: Benny Sundström, Johanneshov, August 1980).

The sun — earth's driving force

Energy from the sun drives life on earth. The motion of the earth on its axis and around the sun gives rise to the seasons and a climate that has made it possible for a wide range of animal and plant life to develop and colonize the surface of the earth.

Sunlight, which is made up of light waves of different wavelengths, propagates at a speed of 300 000 km/s. The journey from the sun to the earth takes about 8 minutes.

To the scientists, sunlight is an example of electromagnetic radiation. A small part of the electromagnetic radiation emitted by the sun is in the form of visible radiation, light, but the non-visible radiation is equally important to us on earth.

Due to the high temperatures existing on the surface of the sun, energy is also emitted in the form of a particle stream, the solar wind. The majority of the particles are ionized hydrogen atoms (protons) and electrons. The solar wind blows through the solar planetary system at a speed of between 300 and 900 km/s. It is deflected in its motion by, for example, the earth's magnetic field which it modifies. The cavity thus formed in the solar wind is called the earth's magnetosphere. The magnetosphere extends from the earth about ten earth radii towards the sun and is stretched into a long tail (hundreds of earth radii) in the direction away from the sun.

A complicated and variable interaction exists between the solar wind and the earth's magnetosphere. The motion of the electrically charged particles that penetrate the magnetosphere is controlled by the magnetic field. In regions around the north and south poles particles can most easily reach the denser atmosphere above the earth. In this situation the particles are decelerated, during collisions with atmospheric gases, and lose their kinetic energy. Some of this energy is absorbed by the atmospheric constituents and later converted into light, and this light, which is emitted at an altitude of about 100 km, is called Aurora Borealis (Aurora Australis in the southern hemisphere). The region in the northern hemisphere where it is most likely to observe aurora extends over northern Scandinavia, Siberia, Alaska, and northern Canada.

Kiruna Geophysical Institute (KGI), one of the institutes situated in this region, carries out research into the processes occurring in the magnetosphere.

This brochure describes the institute and some of our research interests.

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Why carry out research in magnetospheric physics?

The type of research conducted at KGI must be classified as basic research. The aim of basic research is to increase knowledge and understanding rather than to find practical applications for existing knowledge. Scientific advances sooner or later find practical uses, but that is the task of applied research. The development of our technological age is based on results from basic research.

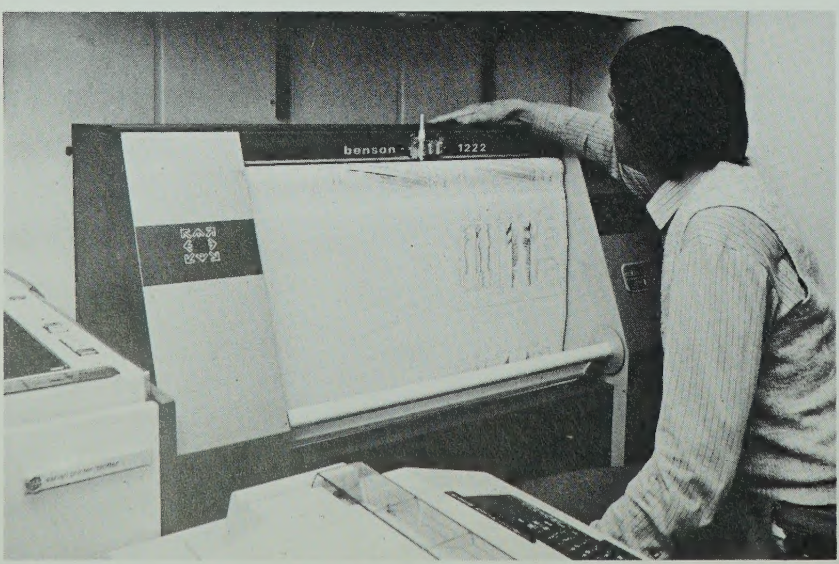
Scientific investigation and basic research arise from man's interest to learn about and explain his surroundings.

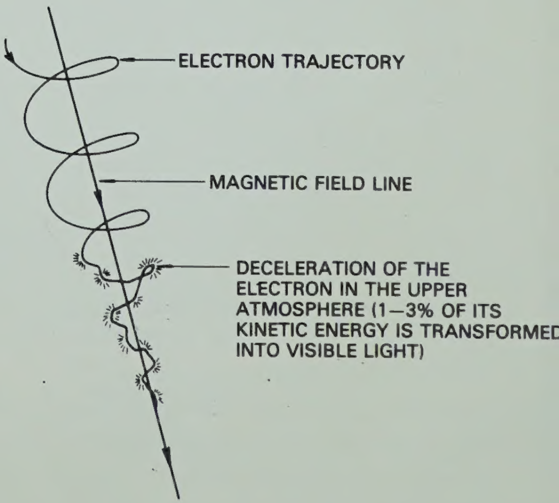
The beautiful and impressive auroral displays have naturally been of interest for scientific investigation from early days.

Magnetospheric physics — the physics of near earth space — covers study of the upper atmosphere above the height that traditionally is covered by meteorology out to such a distance that the earth's magnetic field no longer has influence on physical processes. We may also include magnetospheric physics of other planets. The development of the space age, beginning in the 1950s, has provided much better opportunities for magnetospheric research. The research KGI carries out by means of satellites, rockets, and ground based instruments is aimed to increase our knowledge of how radiation (particle or electromagnetic) interacts with particles and/or electric and magnetic fields in the magnetosphere. This research demands that large amounts of data are collected and analysed. It is also important that ground based observations are made simultaneously from many places since the phenomena studied are global in nature and measurements made at one place are difficult to relate to large scale phenomena.

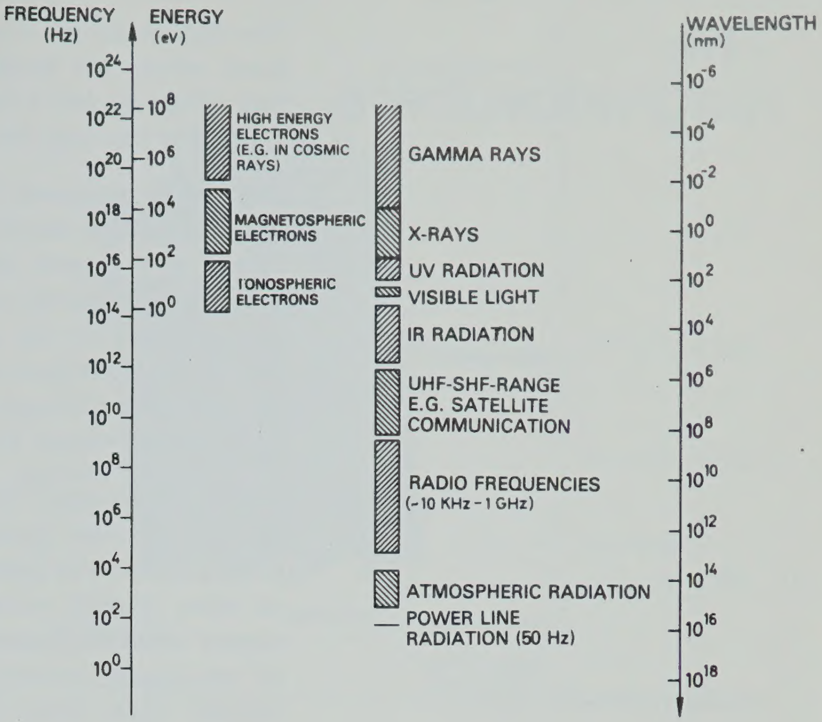
Despite the fact that we pursue basic research our research does have bearing on more practical work. The region in space we study contains charged particles whose motion is dominated by electromagnetic forces — matter in such a state is called a plasma. More than 99.9% of the matter in the universe exists in the form of plasma. Many fundamental plasma processes can only be studied in space since the possibilities to create and maintain plasma in a laboratory on earth are very limited. Processes occurring in plasmas are very important in fusion energy research.

Analysis of data. KGI has a powerful computer system which is used to analyse the large amount of data which is obtained from satellite, rocket, and ground based experiments.




ELECTRON TRAJECTORY
MAGNETIC FIELD LINE
DECELERATION OF THE ELECTRON IN THE UPPER ATMOSPHERE (1—3% OF ITS KINETIC ENERGY IS TRANSFORMED INTO VISIBLE LIGHT)

The auroral discharge takes place in a region of space called the ionosphere.



Energy flux from the sun in different energy bands. Note the small fraction of the total flux within the visible region. The left hand side shaded areas describe particles that are emitted from the sun or produced by secondary effects. The right hand side shaded areas describe electromagnetic radiation.

The energy flux from the sun and its route to the earth

Our earth continuously receives energy from the sun and other sources in space. The energy flux is carried by electromagnetic radiation and charged particles.

Electromagnetic radiation is a transport of energy through radiation quanta called photons. Each photon has a characteristic frequency, which also is a measure of its energy — the higher the frequency the higher the photon energy. The electromagnetic spectrum covers an enormously large range of frequencies. The part that is of importance to the energy balance of the earth encompasses photons with frequencies from about 10^{11} Hz and up. Here is included for example visible light that has frequencies from $4 \cdot 10^{14}$ to $7.5 \cdot 10^{14}$ Hz, and UV-radiation that has frequencies just above the upper frequency limit of the visible light. The most energetic (and thus with the highest frequency) photons, so called cosmical gamma quanta, can have frequencies more than one million times larger than the frequencies of visible light.

The electromagnetic radiation that reaches the earth is scattered on its way through the atmosphere. Only a small fraction reaches the ground, while the main portion (for example almost all the UV-radiation) is absorbed at higher altitudes. Most of the absorption takes place through ionization, a process in which the photon gives its energy to one of the outer electrons in an atom so that the electron is detached. In the earth's atmosphere there is an altitude range between about 80—400 km where electrons are abundant. The physical processes in this region, the so called ionosphere, are studied at KGI.

The particle flux in the vicinity of the earth consists mostly of electrons and protons which have been emitted from the sun in its combustion processes. The particles have considerable velocities. When they reach the earth their kinetic energy can be equivalent to what it would be in a gas with a temperature of more than one million degrees.

Those particles that reach the earth's atmosphere are slowed down through collisions with atoms and molecules in the upper atmosphere transferring their energy to the atmospheric particles. The energy exchange leads to secondary phenomena like for example auroral light emission, ionization, chemical reactions, and heating of the atmosphere.

A moving electrically charged particle in a magnetic field follows a trajectory determined by the shape and strength of the magnetic field. The earth's magnetic field in this way guides the particle flux from the sun within a large region called the magnetosphere. A consequence of this guiding is that the particle flux only reaches the earth's atmosphere in two ringshaped regions around the poles. The study of the physical processes in the magnetosphere is an important part of KGIs research programme.

The magnetosphere

Drawing: N Peterson.

The magnetosphere is the region of space where the earth's magnetic field influences and is influenced by the plasma flux from the sun.

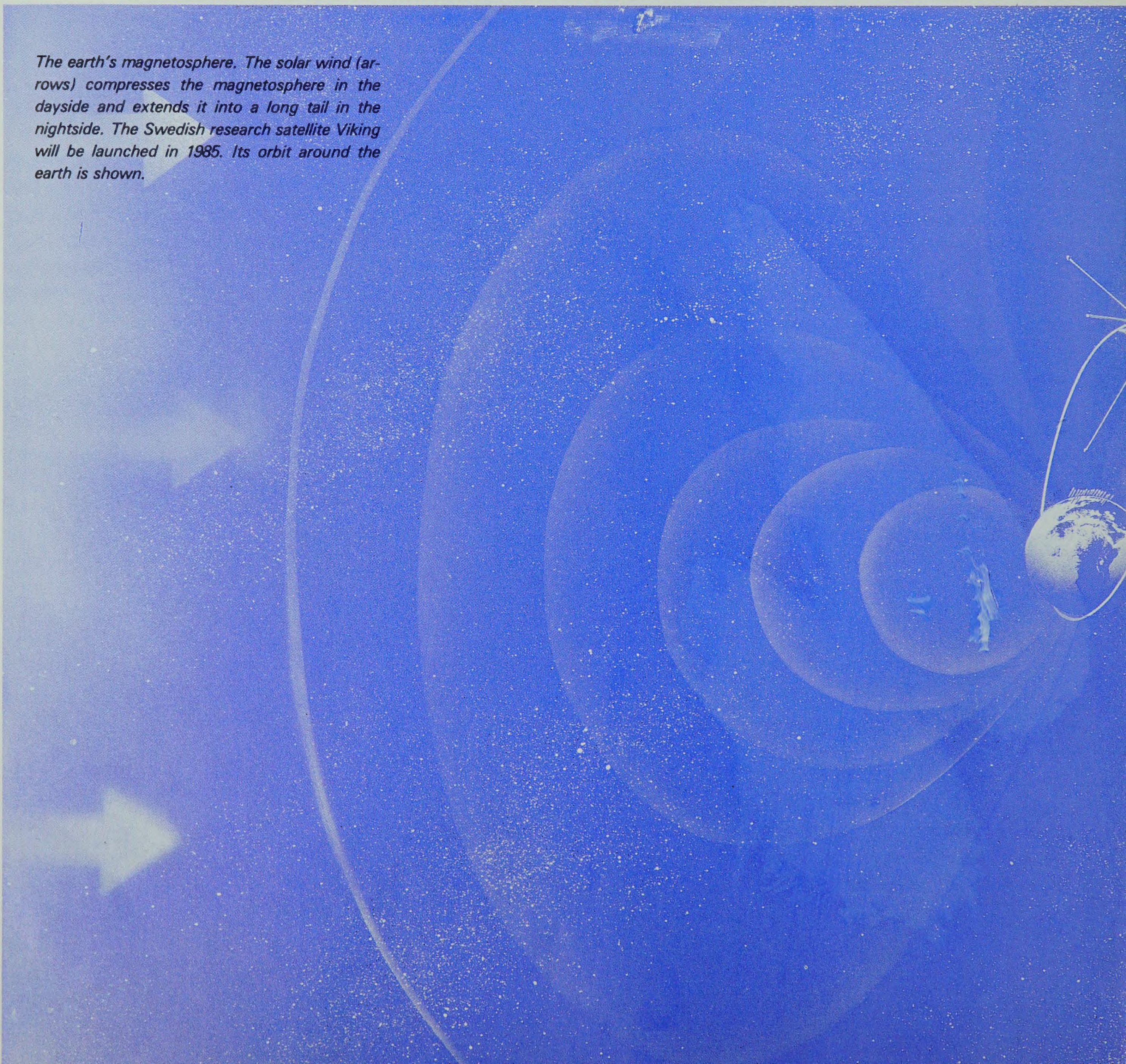
The earth's magnetic field and to some extent the electric field in the vicinity of the earth determine the position of the auroral zones. Due to the symmetry of the geomagnetic field the northern lights and southern lights occur simultaneously and are usually mirror images of each other.

It is only in the north that the auroral zone comes near populated areas. In the southern hemisphere the auroral zone extends mainly over the oceans between Antarctica, Australia and South America. Thus, the northern lights have been studied and observed to a much greater extent than the southern lights.

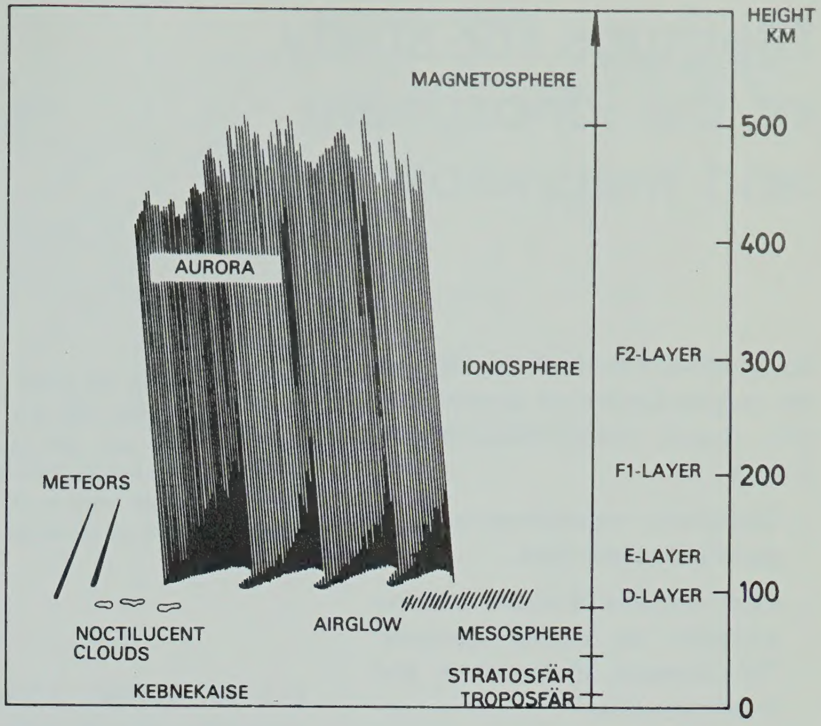
The aurora has always fascinated man and it is natural that most speculations about this phenomenon have been made by people living in the northern countries, close to the auroral zone.

Near to the earth, the earth's magnetic field is similar in form to that produced by a simple bar magnet. There exist a magnetic north and a magnetic south pole on the earth.

The magnetosphere is not symmetric. The stream of particles from the sun (the solar wind) compresses the magnetosphere in the dayside and extends it into a long tail in the nightside of the earth.



The earth's magnetosphere. The solar wind (arrows) compresses the magnetosphere in the dayside and extends it into a long tail in the nightside. The Swedish research satellite Viking will be launched in 1985. Its orbit around the earth is shown.



Altitude distribution of various light emitting phenomena and classification of the ionosphere regions. The aurora is produced along the magnetic field lines over an extended altitude but is most intense between 100—150 km.

Methods for study of the ionosphere and magnetosphere

KGIs all-sky camera for photography of the aurora. This is a standard camera type that is found in most high latitude observatories. It normally takes a colour photograph of the sky every minute.

Many different methods for study of the magnetosphere are employed at KGI. Ground based measurements include

- Continuous measurements of the earth's magnetic field.
- Measurements of visible radiation emission by all-sky cameras, TV—cameras, photometers, and interferometers.
- Measurements using radio waves. The ionosonde, auroral radar and incoherent scatter radar are active experiments in which radio waves are emitted by an antenna in order to probe the magnetosphere where as the riometer is a passive experiment recording radio waves from space. EISCAT is the most advanced incoherent scatter radar situated in the auroral zone. EISCAT headquarters and one of the three receiving stations are situated in Kiruna. The transmitter is located in Tromsö, Norway.
- Measurements of infrasound (sound of a frequency so low that it is not audible). Infrasound is sometimes created during aurora but the strongest sources are found on the ground, for example hydro-electric power stations.

Many of the measurements described above are carried out routinely by a number of observatories all over the world. KGI is a member of this net of observatories.

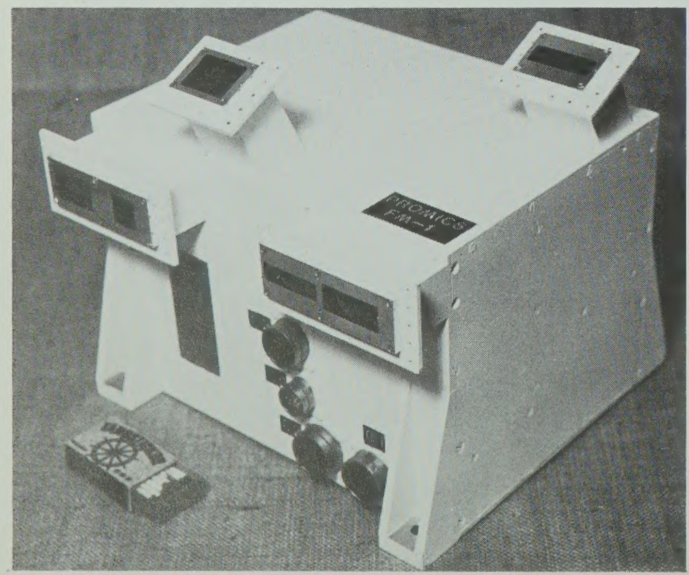
Rockets and satellites are needed to make measurements directly in the magnetospheric plasma. Rockets have a flight time of 5–10 minutes and are used for detailed measurements in the altitude range 100—1000 km. In Sweden rockets are launched from Esrange, near Kiruna. Satellites can explore all regions of the magnetosphere and may have a lifetime of several years.

Rockets and satellites carry a complement of different experiments. Instrumentation is provided to measure, for example, the electric and magnetic fields, plasma properties, and auroral light. Different research groups build different experiments. In Kiruna we have specialized in instruments measuring the energetic particles that can create the aurora.

To date we have flown experiments on about 40 rockets and seven satellites. We have also developed an extensive particle instrument for Viking, the first Swedish satellite.

Results from rocket and satellite measurements are often combined with ground based measurements. For example a rocket may make detailed localized plasma measurements while a TV camera records the aurora from the ground in order to see the large scale spatial and temporal behaviour.

Theoretical studies attempt to derive models for the processes occurring in the magnetosphere and to compare predictions with observations. KGI has a theoretical research group in Umeå.



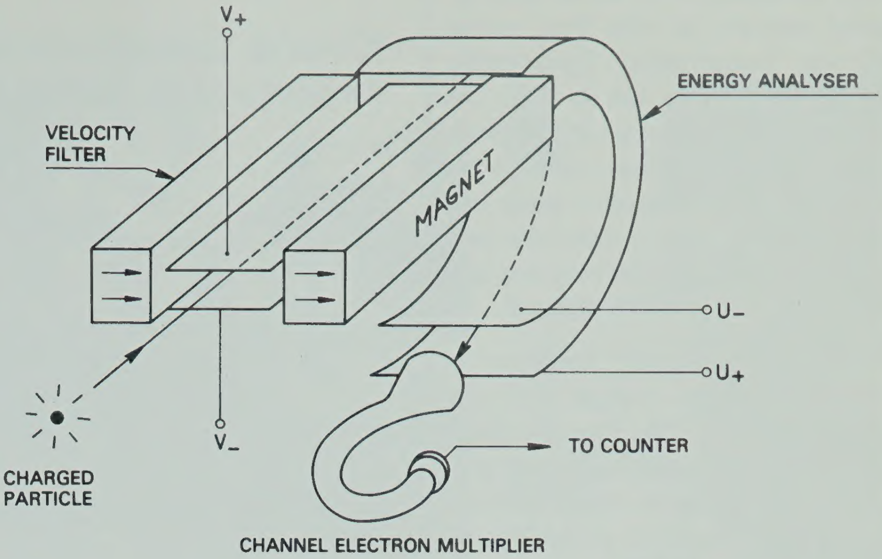
A particle experiment flown in a Soviet satellite in 1978. Since 1968 KGI has flown experiments in 7 different satellites.

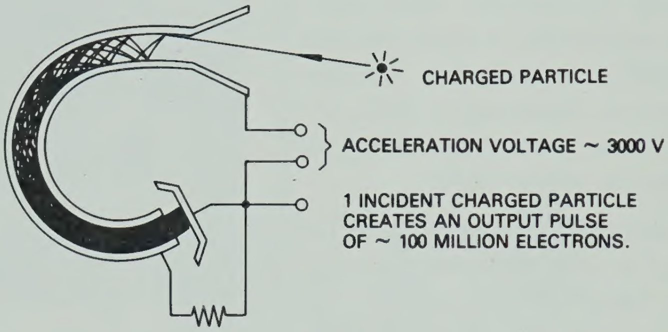
Measurement techniques

There are many different ways to investigate the magnetospheric plasmas. KGI has specialized in instruments that determine the composition, density, and velocity distribution of the plasma particles. The negatively charged particles consist almost entirely of electrons and the electron velocity is easily related to the electron energy since we know the electron mass. A number of positively charged particles (ions) of different mass exist in the magnetosphere and the ion composition varies considerably with time and position in the magnetosphere. It is thus useful to be able to determine the energy distribution separately for each ion type, e.g. H^+, He^+, and O^+.

The energy interval in which most of the so called 'hot' magnetospheric plasma exists extends from a few tens of electron volt up to a few thousand electron volt. In this energy range we normally use a so called 'open' detector behind an energy and a mass determining section. The 'open' detector more or less acts as a counter for every particle it collects and is usually formed of a spiral semiconducting glass tube as illustrated in the lower figure. A particle entering the tube creates secondary electrons which are accelerated down the tube due to the voltage applied across the tube. The secondary electrons create further electrons when they collide with the walls of the tube and the final cascade of electrons often amounts to 10 to 100 million. This cascade creates a charge pulse which can be amplified and counted.

The energy and mass determining system is placed in front of this detector and consists of an electrostatic energy analyser or a combination of a velocity filter and an energy analyser as shown in the top figure.




CHARGED PARTICLE
ACCELERATION VOLTAGE ~ 3000 V
1 INCIDENT CHARGED PARTICLE CREATES AN OUTPUT PULSE OF ~ 100 MILLION ELECTRONS.

By varying the voltage across the plates of the energy analyser it is possible to determine the energy distribution of the electrons and/or ions. The velocity filter consists of a magnetic and an electric field at right angles to each other. The magnetic field is created by strong permanent magnets. In the velocity filter the magnetic and electric forces on a charged particle are balanced so that only particles with a particular velocity can pass through the filter. The energy analyser acts in a similar way, but it only passes particles of a particular energy. A system such as this gives information on the velocity and energy of the particles that reach the detector and thus we can determine the particle mass per unit charge.

As we also wish to know from what direction the particles come, we make use of several particle spectrometers pointing in different directions in the experiment. The rocket or satellite spin is often used to cover even more directions.

The inauguration of Kiruna Geophysical Institute (at that time named Kiruna Geophysical Observatory (KGO)) took place July 2, 1957. The Governor of Norrbotten at that time, Manfred Näslund, was proud to say that the most important stage had been reached after a more than ten-year-long period of planning and building.

The Royal Swedish Academy of Sciences was the head of KGO until July 1, 1973. At that time the observatory became an independent governmental research institute (KGI) under the jurisdiction of the Ministry of Education and Cultural Affairs and with the National Board of Universities and Colleges (UHÄ) as the central government authority.

KGI has departments in Uppsala, Uppsala Ionospheric Observatory (UIO) (since 1976), at Umeå University (1967), in Lycksele, Lycksele Ionospheric Observatory (1973), and in Sörfors, the Laboratory for Mechanical Waves (1978).

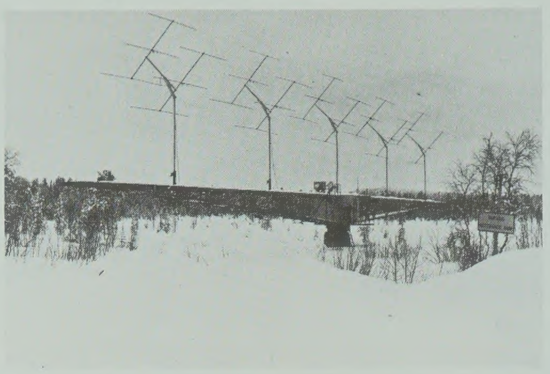
The scientific operation in Kiruna had started as early as in 1948 when professor Olov Rydbeck installed a panoramic ionosonde in a little barrack provided by the town of Kiruna. Since then the research activities have increased and today KGI is the largest organization in Sweden in the field of space plasma physics. The programme includes observatory measurements at Kiruna (68° N), Lycksele (65° N) and Uppsala (60° N), experimental and theoretical research, and postgraduate courses. Regarding postgraduate studies, KGI is a department of Umeå and Uppsala universities.

In 1957 KGI had a staff of 5 persons and in 1984 about 90. Its budget for the financial year 1984/85 amounts to about SEK 29 million.

Magnetospheric and ionospheric physics is a research field where international co-operation is well developed. Scientists from all over the world regularly visit the institute and KGI has arranged several international conferences.

Kiruna Geophysical Institute (KGI)

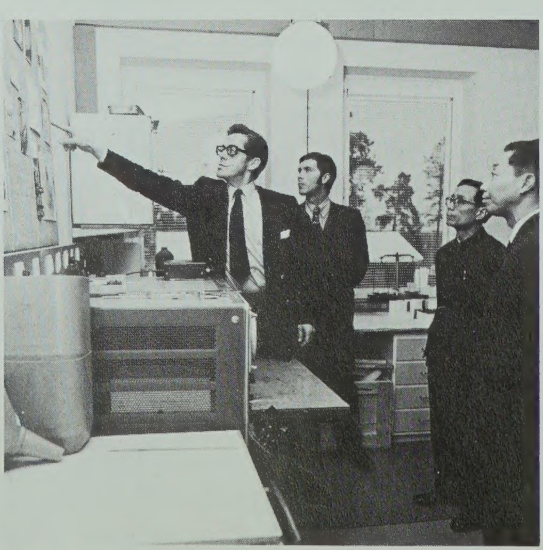
8 km east of Kiruna C 67.841° N, 20.412° E



A rotating 60 m long boom that carries optical instruments and cosmic radio noise instruments whose antennas are clearly seen.

Work in the electronics workshop. Here satellite, rocket, and ground based instruments are designed and built. KGI also has extensive equipment for testing and calibrating these instruments.

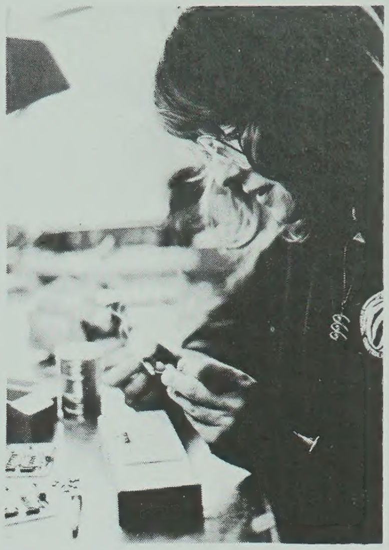
A rocket payload. KGI develops and performs approximately one rocket experiment each year.



KGI has frequent contacts with scientists from other countries. Here the director Bengt Hultqvist with a Chinese delegation. International symposia are also arranged to promote personal contacts with scientists in the same field and exchange scientific results.

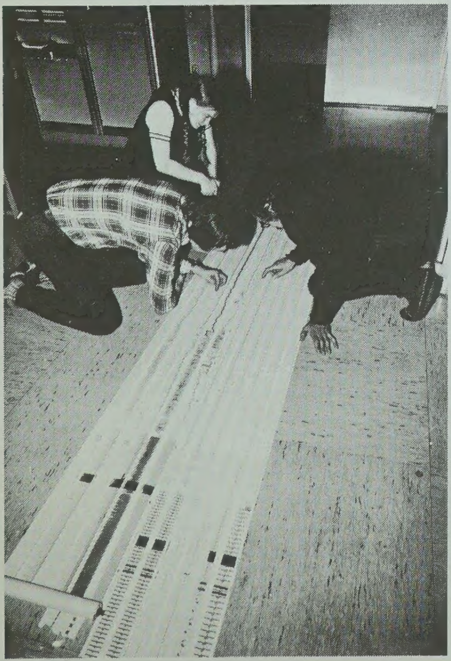
The mechanical workshop (upper left).

Precision soldering (upper right).



Uppsala Ionospheric Observatory.

A first look at rocket data (lower left). There are 30 physicists at the institute, 13 in Kiruna, 6 in Umeå, and 11 in Uppsala.



Lycksele Ionospheric Observatory (lower right).

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